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USE AND ECONOMY OF CONCRETE PIPE IN IRRIGATION SYSTEMS

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USE AND ECONOMY OF CONCRETE PIPE IN IRRIGATION SYSTEMS

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SYNOPSIS

This paper discusses the various factors to be considered in the determination of the economy in the use of concrete pipe in irrigation systems. Uses for concrete pipe are divided into three categories: structures, supply lines, and distribution systems; and economic comparisons are made with other types of construction. Economic considerations are also discussed in relation to saving of water, reduced cost of operation and maintenance, value of right of way, and reduction of seeped areas caused by losses through pervious canal sections. It is also emphasized that unless concrete pipe can be justified on a financial basis, its use in irrigation work will be decidedly limited.

The use of any material or product is usually dictated to an important degree by economic considerations. Also, this economy must be based on the life of the product and the cost of upkeep or maintenance as well as the first cost of the installation. Therefore, the use of concrete pipe in irrigation systems is necessarily related to the economy, based on over-all considerations or, in other words, the annual cost computed over the life of the project works.

When the early settlers in the Salt Lake Basin first diverted water from the mountain streams to supplement the sparse rainfall of that area, many of the economic factors of importance today did not exist. The water supply was adequate for the requirements, no storage was necessary, no value had been placed on right of way, and many of the miscellaneous items of cost now incident to irrigation development were not in evidence. In fact, a man's interest in the irrigation system was measured by the labor contributed towards its construction and maintenance. In general, similar economic conditions existed in all of the early developments of this nature.

With the rapid settlement of the West, starting in 1890, the expansion of irrigation was greatly accelerated. Irrigation laws recognizing priorities and ownership of water came into being; storage was established as a necessary factor in the ultimate development of any regional water supply. In fact, water for irrigation was recognized as having a definite dollar value until today when the demand greatly exceeds the supply in most areas, the question facing us is how much expense we can justify in our efforts to eliminate losses or waste.

Concrete pipe has been used in irrigation systems in the State of California since 1885. The Bureau of Reclamation records several installations in the years 1906 to 1908, and by 1912 specifications were prepared for reinforced

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concrete pipe on the Boise Project in Idaho. In 1919 the Bureau of Reclamation contracted with the Lock Joint Pipe Company for the use of their patents, and through this agreement and others, extensive installations were made on various projects, which up to 1947 had aggregated a total of 700,000 linear feet manufactured and installed by the Bureau; in addition to this, approximately 5,000,000 linear feet have been installed by commercial organizations or contractors on Bureau projects. Due to lack of records, it would be very difficult to estimate the amount of concrete pipe in service on the many private irrigation systems. Needless to say, it would undoubtedly exceed the above figures many times.

Pipe in irrigation systems may be divided into three categories: (1) pipe in structures such as siphons, culverts, both under canals and roads, and canal turnouts, (2) pipe in supply lines, and (3) pipe in distribution systems.

It is probable that the use of pipe in structures for the conveyance of irrigation water under rivers, creeks, or other drainage channels, and under railroads and highways, and for the carriage of drainage waters under canals, was the first important use in irrigation systems. Here it is simply the choice of precast units in place of monolithic concrete construction, usually justified on a cost basis only.

When concrete pipe is mentioned, it is natural to think of precast units manufactured at a central plant. In the past, however, and even at the present time, cast-in-place concrete pipe has been used for the larger installations. In years past, monolithin concrete construction was actually cheaper than the precast units for diameters greater than 42 inches. However, with the increase in labor costs in the past 15 years and the many improvements in pipe manufacture, this comparison has changed until the precast pipe is competitive up to 84 inches, or twice the diameter formerly considered. For the purposes of this discussion, only precast construction will be considered. Ordinarily, the precast concrete pipe is very suitable for these structures when it meets the necessary design requirements and competes in cost with other types of construction. For inverted siphons under rivers, creeks, etc., the precast pipe is especially adaptable, as it may be reinforced to meet any ordinary external loading or internal pressure head, and, if necessary, steel liners or cylinders may be provided where the head is excessive. Many structures of this type have been in operation for years with no apparent deterioration and at a minimum of maintenance cost.

In the early days of irrigation development, the flume was considered to be the ideal structure to convey irrigation canals over river or creek channels or other depressions, and many of these structures were built of various types and materials. Concrete and timber were extensively employed, but probably the most popular was the sheet metal semicircular section supported on timber or structural steel substructure on concrete footings. These flume installations served a useful purpose and in first cost almost invariably proved to be less expensive than any other type of structure. Many are still in use, especially those of smaller capacities. However, due to operating difficulties, maintenance cost, and limited life, replacements have usually resulted in the construction of inverted siphons, with precast concrete units being favored where adaptable. From 1925 through 1940, reinforced concrete pipe was extensively used in these replacements, and in some cases, some with hydrostatic heads of over 200 feet were used and have operated without trouble or unusual maintenance cost since that time.

Concrete pipe supply lines are especially numerous in connection with municipal waterworks construction, and while of less importance in irrigation

systems, we still have many installations which have proved entirely successful. Notable examples of this nature are the Salt Lake Aqueduct, extending 42 miles from the Deer Creek Reservoir on the Provo River to the suburban areas of this city, and the 72-mile double barrel San Diego Aqueduct, extending from the end of the San Jacinto Tunnel on the Colorado River Aqueduct to San Vicente Reservoir. These features may be considered as water supply for both municipal and irrigation purposes. The Weber Basin Project development now under way a short distance north of here likewise will involve many miles of large-size concrete pipe lines, part of which have recently been placed under contract. Other installations of large size pipe include pump discharge lines and power penstocks on some of the multipurpose projects. Surges incident to power penstock operation frequently involve design considerations which are more favorable to steel pipe because of its greater flexibility.

By far the most important use of concrete pipe in irrigation work, and exceeding other installations in length and cost, is in the distribution systems. As mentioned previously, records of the Bureau of Reclamation indicate over 1,000 miles of such construction besides the far greater mileage on private projects all over the West. It is also worth mentioning here that in some of the foreign countries where irrigation is necessary concrete pipe lines are extensively used.

As mentioned previously, the use of any product is ordinarily dictated by economic considerations. For many years there have been data accumulated on the comparative costs of concrete pipe and that of other materials, particularly wood stave and steel pipe. For an extended period prior to 1930, wood stave pipe was definitely competitive with the other types. However, with the increasing scarcity of timber and the definite limit to the life of the wood stave installation, it has been eliminated from consideration in most current designs. It is generally agreed that steel pipe has been and is more competitive with concrete pipe than any other type. However, there are limitations to any comparisons of this nature. For diameters of 12 inches and over and for pressure heads of less than 200 feet, the precast concrete pipe is ordinarily a less expensive installation than steel and, with a decided advantage in maintenance cost, is considered to be cheaper than steel. However, for high head requirements, the steel pipe has been recognized as competitive, especially in first cost, with the maintenance cost usually being favorable to the concrete. Concrete cylinder pipe for high head installation has been used extensively in the municipal water supply field, and there are many hundreds of miles of such pipe operating successfully under pressures from 350 to 650 feet. Developments in flexible joints in concrete pipe during the past 15 years have played an important part in the promotion of its use in irrigation work as well as in other fields of consideration.

The principal economy in the use of concrete pipe in irrigation systems must be based on the saving of water. If water could be taken from the source, such as a running stream or a storage reservoir, and applied directly to the cropped area without conveyance or evaporation losses, the benefits from the water supply would be correspondingly increased. However, most of our water supply problems involve some conveyance features, and on many of our irrigation projects the service area lies many miles from the source of water. Frequently, it is necessary to conduct the water in open channels constructed in pervious material and in seasons of the year when temperatures are at a maximum. Accurate determination of water losses under these conditions is not always practicable. However, on some projects conveyance losses have

reduced farm deliveries to little more than 50% of the total diversions. Even after the water reaches the farmer, delivery losses in his distribution may be appreciable.

Much has been done in recent years in our efforts to reduce water losses in irrigation systems. It is an accepted opinion that evaporation is a very minor part of the loss and that the elimination or reduction of percolation or leakage from the canal would have the most effective results. Consequently, much research has been directed at providing impervious canal linings and at a reasonable cost. This work has been very well worth-while, much has been accomplished, and the program should be continued. However, the fact remains that only by providing a completely closed conduit, properly controlled, can all conveyance losses be eliminated.

While the saving of water is undoubtedly the most important consideration in favor of pipe conduits, there are many others that are worthy of comment. As most concrete pipe lines are buried below the ground level, the right of way required is reduced to a minimum, and even though a reasonable width is required for construction, most installations require little maintenance, and much of the required right of way may be restored to agricultural production. Frequently, high spots or larger areas not accessible to open canals can be reached by closed pressure lines.

Reduction in maintenance cost is another very important advantage. When properly installed, a great percentage of concrete pipe lines is practically free of maintenance expense, and while no structure of this sort may be considered as permanent, there are many records of long service with no evidence of deterioration or replacement. Many of the maintenance costs incident to open channels are greatly reduced or entirely eliminated, such as silt or sand removal, weed control, bank protection, and minor erosion problems.

Closed pipe irrigation systems also contribute greatly to the reduction or elimination of seeped areas. The drainage of seeped or water-logged areas of our irrigation projects is one of the most aggravating and expensive features to be met and sometimes, due to geologic conditions, is almost impossible of accomplishment. By the reduction of water losses in the canal and distribution systems, the seepage problem is prevented at the source. On one large project the reduction in water supply during the past five years has resulted in a water conservation program of providing canal linings and buried pipe lines. A recent analysis of the benefits included the restoration of a large acreage of seeped land besides an appreciable reduction in the maintenance of drainage works. An interesting reaction to this same program has been a suit brought by a small town on the project for destruction of their municipal water supply, which had been dependent on seepage from the irrigation system.

When we have considered the many and varied advantages in the use of concrete pipe in our irrigation systems, we must still convert them into an equation that will indicate whether or not it is good business. It is easy to conceive that we can spend more on such improvements than they are worth, or we can, to use an expression frequently heard, "Price ourselves out of business." So we must carefully weigh the advantages against the cost, taking into consideration not only the direct benefits apparent, such as saving of water and reduced maintenance, but those lesser and more indirect values that have been discussed. We must try to establish the value of these benefits in dollars.

I can well remember a discussion some 40 years ago about the charge for

supplemental water on a certain project, and one man offered the opinion that based on the actual benefit to the crops, a fair value would be 30 ¢per acre foot. Also, during the past year, I noted a short article in a trade magazine which tried to justify a value of $100.00 per acre foot for water applied to irrigated pasture. I am willing to accept some compromise between these two figures.

Everyone knows, but some people fail to realize, the importance of water. Simply stated, it is absolutely essential to all animal and vegetable life. Since earliest history, mankind has congregated wherever fresh water has been available, and water supply has been a contributing factor in the development of civilization. For over two hundred years after the settlement of our continent started, there was adequate space for the production of food where rainfall was plentiful. Gradually, however, we have spread out to the more arid areas, and water supply for agriculture has taken on more importance. For domestic uses, water is worth whatever it costs. But for agricultural pursuits, its value is measured by the increased production. If our irrigated agriculture can not compete with the rain belt, it is out of business. In like manner, increased efficiency in our irrigation designs, construction, and operation and maintenance must be made to pay off in profits to the farmer. If, by providing a pipe line for our irrigation deliveries, we can increase net profits to the user, then only can it be justified.

During the past half century, we have seen the development of great irrigation works, each of which has further reduced the untapped water resources of our country, until today we are faced with the question of trying to make better use of what we have. We have demonstrated that the concrete pipe line will reduce conveyance losses of irrigation water to a minimum, but it is likewise expensive, so how are we going to fit the cost of this facility to the benefits derived?

During the past 15 years, and especially since the end of World War II, there has been a decided increase in the demand for closed irrigation systems. This is especially true in the semitropical areas of the Southwest. During this period, nearly 400 miles of concrete pipe have been placed by the Bureau of Reclamation in the Coachella Valley of Southern California. In the Central Valley of California, nearly 600 miles have been installed or are under contract. Also, nearly 1,000 miles of small-size irrigation pipe have been installed by private projects in the High Plains area of Texas during this same period. Much of this work has been in areas which have been irrigated for many years. Furthermore, there is a decided trend on many systems all over the West toward replacement of open channels with pipe, even on individual farms and small districts where this type of improvement has been considered justified.

Losses of water after it has been delivered to the user are extremely difficult to determine. Factors such as type of soil, care or proficiency of the irrigator, and adequacy of the farm irrigation system are all important. However, little has been done to either measure this loss or reduce it. In recent years, many progressive irrigators have been interested in this matter, and there is a movement at present to gather data on required water consumption and the reduction of farm losses. By containing the water in buried concrete pipe lines instead of field laterals from the point of farm delivery to the point of application to the crop, the saving could well be appreciable. Studies by the Soil Conservation Service along this line have been initiated, and it is anticipated that some results will be available in the reasonable future.

This impetus to the use of concrete pipe has definitely improved techniques in design as well as manufacturing and installation processes and undoubtedly has been a factor in reducing costs. It is the opinion of some that the advancement in this respect in the past five years has been greater than in any other 20 years in the life of the industry. Basic improvements in concrete, both plain and reinforced, and in the development of gasket materials, particularly rubber, have been reflected in the finished pipe, so that today we are dealing with a more reliable and durable product than in the past. Under ordinary circumstances, many of the distribution systems requiring pipe below 20 inches in diameter and operating under pressure heads of less than 20 feet are constructed of unreinforced concrete pipe and provided with mortar joints of some type. For installations requiring larger sizes or greater heads, reinforcement is necessary, and flexible joints will be justified. I am sure that there are plenty of exceptions to these limits of both size and heads where unreinforced pipe has proved satisfactory, and the mortar joint has been tight. However, I believe good design will dictate criteria somewhere near these figures. The development of the rubber gasket joint has been a definite step forward, and the part of the manufacturers in this advancement has been substantial. Today it is believed that the cost of the flexible rubber gasket seal has been reduced to a figure competitive with the less effective mortar joint. The weakness in the mortar joint is usually due to slight settlement after the mortar is placed, causing cracks that result in progressive leakage and possible damage to the entire pipe line.

In the planning of a concrete pipe installation on an irrigation project, consideration should be given to the proper design to meet the hydraulic and structural requirements. Specifications should be prepared to insure the quality of the product and its proper installation. Requirement for satisfactory performance over one to three years is sometimes stipulated to insure adequate workmanship and material. Good engineering dictates the elimination of unnecessary refinements or gold plating. However, nothing is more aggravating or expensive than a system that causes difficulty in operation and maintenance. With a well-designed and constructed concrete pipe installation, whether in the control structures, supply lines or distribution system, operation losses and maintenance problems should be reduced to a minimum.

Then the question is, "Will the savings in water, maintenance, right of way, convenience in operation, and the insurance against failure pay the cost of the system?" In the planning of a new project, it is usually practicable to estimate the cost of the concrete pipe in comparison with an open system and figure these savings against the difference. In the rehabilitation of an open canal system to concrete pipe throughout, the estimate must be computed on another basis, as ordinarily the facilities of the original installation are unusable after the change is effected. In this case, the benefits must carry the entire cost.

Needless to say, expense for improvements to the irrigation system is more readily justified when the crop return is high. On projects with mild climates, long growing seasons and adaptability to fruit and vegetable production with high cash returns, the incentive toward water saving is greater than where these conditions do not prevail. While it is impracticable to give an accurate figure on the cost per acre of providing a pipe distribution system for a given area, it is usually possible to make a fairly reliable estimate of such features. Also, an estimate of the benefits may be made that will indicate the economic relation of the proposed improvement. In accordance with any study of this type, this relation must be computed on an annual basis over the anticipated repayment period of the project cost.

In a summary of this discussion of a matter that has become one of increasing importance and one in which many of us have given much study in recent years, it may be concluded that the use of concrete pipe in irrigation systems has been and is a success. Some failures have been experienced, but these were more often the result of improper installation than any weakness in the pipe. Also, the trouble-free installations have so far exceeded the failures as to make them almost negligible. The improvements in design, manufacture and installation have all been constructive, resulting in reduction in cost as well as in a definite betterment of the finished pipe line. Consequently, the problem is resolved into one of economics. A careful and comprehensive analysis of costs and benefits will frequently result in a balance in favor of the pipe for the type of installation required. I am also inclined to believe that the intangible factors such as convenience of operation and insurance against trouble will frequently be enough to materially increase the advantages.

We can look forward to a definite continuation of and increase in the use of concrete pipe in irrigation systems.

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c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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